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NATIONAL BUREAU OF STANDARDS REPORT

5123

QUARTERLY REPORT

ON

EVALUATION OF REFRACTORY QUALITIES OF
CONCRETES FOR JET AIRCRAFT WARM-UP, POWER CHECK,
MAINTENANCE APRONS, AND RUNWAYS

by

W. L. Pendergast, E. C. Tuma and L. E. Mong
and R. A. Clevenger



U. S. DEPARTMENT OF COMMERCE
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Refractories Section
Mineral Products Division

Sponsored by
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1. INTRODUCTION

This phase of the project includes the determination of the cause or causes of failure that occur in concrete aprons and runways exposed to jet exhaust gases. A combustion chamber that delivers hot gases at velocities and temperatures approximating those of field conditions is being used. The approach includes instrumentation of the concrete test panels to determine the heat gradients and stresses set up during flame impingement at several locations on the test area and at varying depths below the surface.

2. ACTIVITIES

2.1 Concrete with Diabase Aggregate

As previously reported^{1/} a concrete was designed with diabase aggregate. A batch was mixed, specimens were fabricated.

Results of preliminary tests on the diabase aggregate, the design of the concrete mix using the aggregate, and the properties of the fresh concrete follow:

	<u>Coarse</u> ^{2/}	<u>Fine</u> ^{2/}
Absorption	0.6	1.54
Bulk Specific Gravity (SS Dry)	2.96	2.87
Percent loss in Los Angeles		
Abrasion Test - - - - -	25.9	
Ratio of coarse-to-fine		
aggregate - - - - -	65 to 35	

^{1/} NBS Report 4869, October 5, 1956.

^{2/} The properties of the aggregate were determine on the same sizings as used in concrete.

Gradation

<u>Coarse</u>		<u>Fine</u>	
U. S. Standard	Percent	U. S. Standard	Percent
Sieve		Sieve	
on 1	22	No. 8	16
3/4	30	16	20
1/2	18	30	29
3/8	15	50	25
No. 4	15	100	9
		Thru 100	1

Properties of Fresh Concrete

Proportions, by weight: Cement) to coarse and to fine aggregate)	1 : 3.18 : 1.71
Cement content ^{3/}	7.31 sacks/yd ³ of concrete
Vinsol resin	0.01% by weight of cement
Water content	32.7 37.7 gals/yd ³ of concrete
Air content	2.2% gravimetric method
Slump	2.25 inches
Weight of fresh concrete	161.44 lbs/ft ³
Water cement ratio	0.40
Remarks	Easily placed but harsh

The flexural strength of the concrete after curing for 28 days in fog-room was 845 psi. Heating to 500°C for five hours (complete immersion) reduced the strength to 305 psi. Heating to 750°C resulted in a further loss of strength to 100 psi. The cured specimens failed by aggregate fracture and the heated specimens by bond failure. Two test panels fabricated from this concrete were subjected to the jet blast. Both had been cured for 28 days in the fog-room, one had

^{3/} Designed as a seven-sack mix, calculated to 7.3.

APPENDIX

TABLE I		TABLE II	
Year	Value	Year	Value
1900	100	1905	120
1901	110	1906	130
1902	120	1907	140
1903	130	1908	150
1904	140	1909	160

APPENDIX III

TABLE III		TABLE IV	
Year	Value	Year	Value
1910	170	1915	180
1911	180	1916	190
1912	190	1917	200
1913	200	1918	210
1914	210	1919	220
1920	230	1921	230
1922	240	1923	240
1924	250	1925	250
1926	260	1927	260
1928	270	1929	270
1930	280	1931	280
1932	290	1933	290
1934	300	1935	300
1936	310	1937	310
1938	320	1939	320
1940	330	1941	330
1942	340	1943	340
1944	350	1945	350
1946	360	1947	360
1948	370	1949	370
1950	380	1951	380
1952	390	1953	390
1954	400	1955	400
1956	410	1957	410
1958	420	1959	420
1960	430	1961	430
1962	440	1963	440
1964	450	1965	450
1966	460	1967	460
1968	470	1969	470
1970	480	1971	480
1972	490	1973	490
1974	500	1975	500
1976	510	1977	510
1978	520	1979	520
1980	530	1981	530
1982	540	1983	540
1984	550	1985	550
1986	560	1987	560
1988	570	1989	570
1990	580	1991	580
1992	590	1993	590
1994	600	1995	600
1996	610	1997	610
1998	620	1999	620
2000	630	2001	630
2002	640	2003	640
2004	650	2005	650
2006	660	2007	660
2008	670	2009	670
2010	680	2011	680
2012	690	2013	690
2014	700	2015	700
2016	710	2017	710
2018	720	2019	720
2020	730	2021	730
2022	740	2023	740
2024	750	2025	750
2026	760	2027	760
2028	770	2029	770
2030	780	2031	780
2032	790	2033	790
2034	800	2035	800
2036	810	2037	810
2038	820	2039	820
2040	830	2041	830
2042	840	2043	840
2044	850	2045	850
2046	860	2047	860
2048	870	2049	870
2050	880	2051	880
2052	890	2053	890
2054	900	2055	900
2056	910	2057	910
2058	920	2059	920
2060	930	2061	930
2062	940	2063	940
2064	950	2065	950
2066	960	2067	960
2068	970	2069	970
2070	980	2071	980
2072	990	2073	990
2074	1000	2075	1000
2076	1010	2077	1010
2078	1020	2079	1020
2080	1030	2081	1030
2082	1040	2083	1040
2084	1050	2085	1050
2086	1060	2087	1060
2088	1070	2089	1070
2090	1080	2091	1080
2092	1090	2093	1090
2094	1100	2095	1100
2096	1110	2097	1110
2098	1120	2099	1120
2100	1130	2101	1130
2102	1140	2103	1140
2104	1150	2105	1150
2106	1160	2107	1160
2108	1170	2109	1170
2110	1180	2111	1180
2112	1190	2113	1190
2114	1200	2115	1200
2116	1210	2117	1210
2118	1220	2119	1220
2120	1230	2121	1230
2122	1240	2123	1240
2124	1250	2125	1250
2126	1260	2127	1260
2128	1270	2129	1270
2130	1280	2131	1280
2132	1290	2133	1290
2134	1300	2135	1300
2136	1310	2137	1310
2138	1320	2139	1320
2140	1330	2141	1330
2142	1340	2143	1340
2144	1350	2145	1350
2146	1360	2147	1360
2148	1370	2149	1370
2150	1380	2151	1380
2152	1390	2153	1390
2154	1400	2155	1400
2156	1410	2157	1410
2158	1420	2159	1420
2160	1430	2161	1430
2162	1440	2163	1440
2164	1450	2165	1450
2166	1460	2167	1460
2168	1470	2169	1470
2170	1480	2171	1480
2172	1490	2173	1490
2174	1500	2175	1500
2176	1510	2177	1510
2178	1520	2179	1520
2180	1530	2181	1530
2182	1540	2183	1540
2184	1550	2185	1550
2186	1560	2187	1560
2188	1570	2189	1570
2190	1580	2191	1580
2192	1590	2193	1590
2194	1600	2195	1600
2196	1610	2197	1610
2198	1620	2199	1620
2200	1630	2201	1630
2202	1640	2203	1640
2204	1650	2205	1650
2206	1660	2207	1660
2208	1670	2209	1670
2210	1680	2211	1680
2212	1690	2213	1690
2214	1700	2215	1700
2216	1710	2217	1710
2218	1720	2219	1720
2220	1730	2221	1730
2222	1740	2223	1740
2224	1750	2225	1750
2226	1760	2227	1760
2228	1770	2229	1770
2230	1780	2231	1780
2232	1790	2233	1790
2234	1800	2235	1800
2236	1810	2237	1810
2238	1820	2239	1820
2240	1830	2241	1830
2242	1840	2243	1840
2244	1850	2245	1850
2246	1860	2247	1860
2248	1870	2249	1870
2250	1880	2251	1880
2252	1890	2253	1890
2254	1900	2255	1900
2256	1910	2257	1910
2258	1920	2259	1920
2260	1930	2261	1930
2262	1940	2263	1940
2264	1950	2265	1950
2266	1960	2267	1960
2268	1970	2269	1970
2270	1980	2271	1980
2272	1990	2273	1990
2274	2000	2275	2000
2276	2010	2277	2010
2278	2020	2279	2020
2280	2030	2281	2030
2282	2040	2283	2040
2284	2050	2285	2050
2286	2060	2287	2060
2288	2070	2289	2070
2290	2080	2291	2080
2292	2090	2293	2090
2294	2100	2295	2100
2296	2110	2297	2110
2298	2120	2299	2120
2300	2130	2301	2130
2302	2140	2303	2140
2304	2150	2305	2150
2306	2160	2307	2160
2308	2170	2309	2170
2310	2180	2311	2180
2312	2190	2313	2190
2314	2200	2315	2200
2316	2210	2317	2210
2318	2220	2319	2220
2320	2230	2321	2230
2322	2240	2323	2240
2324	2250	2325	2250
2326	2260	2327	2260
2328	2270	2329	2270
2330	2280	2331	2280
2332	2290	2333	2290
2334	2300	2335	2300
2336	2310	2337	2310
2338	2320	2339	2320
2340	2330	2341	2330
2342	2340	2343	2340
2344	2350	2345	2350
2346	2360	2347	2360
2348	2370	2349	2370
2350	2380	2351	2380
2352	2390	2353	2390
2354	2400	2355	2400
2356	2410	2357	2410
2358	2420	2359	2420
2360	2430	2361	2430
2362	2440	2363	2440
2364	2450	2365	2450
2366	2460	2367	2460
2368	2470	2369	2470
2370	2480	2371	2480
2372	2490	2373	2490
2374	2500	2375	2500
2376	2510	2377	2510
2378	2520	2379	2520
2380	2530	2381	2530
2382	2540	2383	2540
2384	2550	2385	2550
2386	2560	2387	2560
2388	2570	2389	2570
2390	2580	2391	2580
2392	2590	2393	2590
2394	2600	2395	2600
2396	2610	2397	2610
2398	2620	2399	2620
2400	2630	2401	2630
2402	2640	2403	2640
2404	2650	2405	2650
2406	2660	2407	2660
2408	2670	2409	2670
2410	2680	2411	2680
2412	2690	2413	2690
2414	2700	2415	2700
2416	2710	2417	2710
2418	2720	2419	2720
2420	2730	2421	2730
2422	2740	2423	2740
2424	2750	2425	2750
2426	2760	2427	2760
2428	2770	2429	2770
2430	2780	2431	2780
2432	2790	2433	2790
2434	2800	2435	2800
2436	2810	2437	2810
2438	2820	2439	2820
2440	2830	2441	2830
2442	2840	2443	2840
2444	2850	2445	2850
2446	2860	2447	2860
2448	2870	2449	2870
2450	2880	2451	2880
2452	2890	2453	2890
2454	2900	2455	2900
2456	2910	2457	2910
2458	2920	2459	2920
2460	2930	2461	2930
2462	2940	2463	2940
2464	2950	2465	2950
2466	2960	2467	2960
2468	2970	2469	2970
2470	2980	2471	2980
2472	2990	2473	2990
2474	3000	2475	3000
2476	3010	2477	3010
2478	3020	2479	3020
2480	3030	2481	3030
2482	3040	2483	3040
2484	3050	2485	3050
2486	3060	2487	3060
2488	3070	2489	3070
2490	3080	2491	3080
2492	3090	2493	3090
2494	3100	2495	3100
2496	3110	2497	3110
2498	3120	2499	3120
2500	3130	2501	3130
2502	3140	2503	3140
2504	3150	2505	3150
2506	3160	2507	3160
2508	3170	2509	3170
2510	3180	2511	3180
2512	3190</		

been stored at 73°F and 50 percent relative humidity for 28 days; the second had been stored for 49 days at the same temperature and humidity. This concrete appears to have the best resistance to the jet blast of any thus far tested.

2.2 Absorption and Evaporation of Water

During Curing and Drying of Concrete

The drying of tile shape specimens, three by three inches, having different thicknesses, and fabricated with concrete designed with different aggregates has been continued. These specimens were vapor proofed on all but one three by three inch face. The results appear in Table 1.

The results indicate that the dimension of the specimen is a factor in:

- 1) The amount of water absorbed during fog-room curing;
- 2) The amount of water evaporated during storing;
- 3) The amount of non-evaporable water in concrete after storage and drying.

The concrete designed with crushed brick aggregate while containing less cement than that designed with crushed olivine aggregate had more combined water after curing and drying. R. C. Valore found in his work on Cellular Concretes^{4/} that brick dust acts as a pozzolan cement.

The concrete tile fabricated with the crushed building brick aggregate and those fabricated with the White Marsh aggregate were stored for nine months after curing. The one-half inch tiles were the only ones that reached water

^{4/} Cellular Concretes by R. C. Valore, Journal of American Concrete Institute, May and June 1954.

Table 1. Effect of Curing and Drying of Concrete

Identification ^a	Mixing Water ^b / %	Cement Content ^c / sacks/yard ³ of concrete	Thickness of Tile ^d / inches	Change in Water Content During ^e		Non-Evaporable Water ^f / %
				Curing ^f / %	Storing ^g / %	
P-O	6.5	7.7	6	+0.83	-0.45	2.46
			4	+0.86	-0.52	2.32
			2	+1.05	-0.83	2.61
			1 1/2	+1.01	-0.94	2.69
			1	+1.40	-0.88	2.92
			1 1/2	+1.36	-1.44	2.93
P-B	8.5	6.5	2	+0.80	-1.90	3.37
			1 1/2	+0.97	-2.09	3.13
			1	+1.08	-2.17	3.30
			1 1/2	+1.76	-2.02	4.28
P-WM	6.3	5.3	2	+1.08	-1.18	2.31
			1 1/2	+1.06	-1.02	2.81
			1	+1.41	-1.09	2.95
			1 1/2	+2.70 ^h	+0.59 ^h	5.37 ^h

^a/ The first letter, P = portland cement; the second letter or letters, O = olive, B = building brick, WM = White Marsh sand and gravel.

^b/ Based on weight of wet mix.

^c/ As calculated.

^d/ All tile were three inches square.

^e/ Cumulative change in water content as determined by change in weight from time specimens were removed from mold (20 hours).

^f/ Fog-room curing, 73°F and 100 percent relative humidity.

^g/ Stored at 73°F and 50 percent relative humidity, vapor proofed on all but one three-inch face.

^h/ Vapor proofing removed before drying.

ⁱ/ Percent water retained after drying to constant weight at 110°C; this value does not take into consideration any carbon dioxide acquired during curing, storing or drying, but affords a comparative estimate of the amount of chemically combined water in the specimen.

^j/ Anomalous results probably due to high cement content of the one-half inch tile.

equilibrium under the conditions of storage i.e. stored at 73°F, 50 percent relative humidity, and vapor proofed on all but one three-inch face. The one-half inch tile fabricated with concrete designed using White Marsh aggregate reached constant weight at seven months storage, the one-half inch tile fabricated with concrete designed using crushed building brick reached constant weight at eight months storage. Those made with concrete using olivine aggregate have not as yet reached constant weights.

2.3 Humidity in Concrete Specimens

A two-month delay in shipment of the miniature hygrometers, that are to be used in correlating humidity, at increasing depths, from the exposed surface, with water loss has deferred this work.^{5/} January 24, is the date now scheduled for delivery.

2.4 High-Alumina Hydraulic Cement

During the period covered by this report a concrete was designed with crushed building brick and a high-alumina hydraulic cement (AlCOA - XCA-25), low in impurities. Specimens fabricated from a trial batch of this concrete developed their maximum strength more rapidly than those fabricated with concrete designed with portland cement. Specimens (16 x 4 x 3 inches) fabricated from this concrete developed a flexural strength of 720 psi during 14 days in the fog-room.

^{5/} The method was described in detail in NBS Report 4869, October 5, 1956.

Additional specimens after the same curing period were heated at 500 and 750°C for 5 hours and tested. The flexural strength of those heated at 500°C was 645 psi and those heated at 750°C was 585 psi. Concretes designed with portland, portland pozzolan, or Lumnite cement, and tested after such heat treatments show a loss in flexural strength of from 50 to 60 percent. X-ray diffraction patterns were made on samples of this concrete, after curing, 500°C heat, and 750°C heat. Careful inspection failed to identify any cement component or a shift in the patterns due to heating. A study of the effect of heating on neat high-alumina cements is included in a current project at this Bureau. The data when available will be included in a future report.

2.5 Pressure Developed in Concrete

During Rapid Rate of Heating

In the study of the pressure developed in concrete, as the temperature is raised at a rapid rate, a bomb was constructed. This bomb was equipped with thermocouples located in different positions in the concrete charge and a pressure gauge to measure the vapor pressure surrounding the concrete specimen. The bomb was first checked for performance using water only and the data from the steam tables was reproduced. The bomb was then charged with a concrete mix and cured in the fog-room, and the only water in the system was that contained in the concrete. During heating at 200°C per hour the pressures and temperatures in the concrete

336

2 4

12.

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charge were recorded. However, the total amount of water present in the system was so small that the volume of the colder connecting tubes served as a condenser for the water vapor driven from the concrete and only small net pressures were observed. These net pressures did not develop till the temperature of the concrete was above 230°C .

Since the pressure gauge must operate at room temperature it will be necessary to fill the voids of the system with a liquid having a very low vapor pressure for the temperature of the test. Samples of such liquids have been obtained including Dow Corning silicone fluid 550, and Esstic Oil 42.

It is noteworthy that only about 23 percent of the water, originally present, was lost from the concrete in the heat treatment which included heating to 310°C and cooling to room temperature in the closed system. Concretes heated in air to such temperatures loose nearly all of their water.

2.6 Mineralogic Examination of Aggregates

A mineralogic examination was made on aggregates submitted by NAVCERELAB. Six aggregates were examined before and after four heat shock treatments (1250, 1500, 1800, and 2000°F). Five samples representing the predominating material occurring in San Gabriel gravel and nine samples not marked for an identification were also examined. The results of the examination occur in Tables 2, 3, and 4.

TABLE 2. EFFECTS OF THERMAL SHOCK TREATMENT

Aggregate NBS No.	Field Condition Before Exposure to Thermal Shock ^{1/}	Thermal Shock			
		1250°F 3-min. 667-668	1500°F 3-min. 726-727	1800°F 3-min. 740-741	2000°F 3-min. 779-780
1	Milky quartz, fairly well rounded, trace of muscovite mica and biotite highly fractured structure, dense.	Not altered much, will hand fracture, will fracture more readily on outside portion. ^{2/}	Open fractures, fractured readily throughout. ^{2/}	More open fracture ^{2/}	Same as 1800°F ^{2/}
2	Schistose, considerable amount of micaceous material, high percentage of quartz. Mica, feldspar, decomposed biotite. Medium dense, fairly friable, badly weathered. ^{2/}	661-662 Very little change in structure.	722-723 Micaceous material shows expansion cracking in weathered specimen, especially, large specimen fractured in various directions along fresh surface.	752-753 Mica not as fresh appearing as in lower fired specimens, medium fracture throughout.	781-782 Badly fractured, quite friable, alteration of micas.
3	One specimen was a two-feldspar biotite granite, quite fresh. One specimen contained mostly quartz with some feldspar and amphibole, garnet also present, rock is compact and quite fresh. ^{1/}	673-674 Alteration of micas and friability depends on the extent of weathering that the specimen underwent. The more the weathering the more destructive the thermal exposure.	720-721 Micaceous material altered, expanding especially on surface, fractured throughout.	744-745 Quite friable; fractured throughout, alteration of micas.	787-788 Less micaceous material than occurred in field specimens, quite friable, failure throughout.
4	Pegmatite sample shows much variation piece to piece. Principal impurity limonite, iron stains penetrating the cracks, recemented quartz grains, occasional manganese stains, leached structure, dense. ^{1/}	665-666 Fresh fracture on surface, finger breaks readily. Where iron oxide is isolated iron turning brownish in color losing its H ₂ O, highly fractured, new fractures.	No sample	750-751 Same as 1250°F sample except iron more altered and more highly fractured.	663-664 Thoroughly fractured
5	Igneous rock, fresh not badly altered, amphibole gneiss, shows altering to chlorite, more feldspar than quartz, altered biotite, epidote. ^{1/}	669-670 Quite friable, not badly cracked, some minerals show alteration on surface, different samples show different degrees of friability.	724-725 Highly fractured, more friable, alteration of minerals increasing.	754-755 Increasing in friability and alteration of minerals.	783-784 No strength
6	Very dense schist, containing mica, feldspar porphyroblasts, some pebbles are coated with calcium carbonate. ^{1/}	675-676 Schist structure very noticeable, not much alteration of minerals.	730-731 Micaceous materials altering, still only slight fracture.	742-743 Slight fracture, still micas oxidizing.	777-778 Highly fractured across feldspar grain, ground mass and feldspar showing alteration.

^{1/} The numbers of the photographs of shock-treated specimens of this aggregate all appeared on this sample.^{2/} Inversion temperature cracks.

TABLE 3

Five samples of the predominating materials that occur in San Gabriel gravel.

Sample No. 1

Rock, in form of rounded pebbles, containing quartz, feldspar, biotite, materials quite fresh.

Sample No. 2

Contains a two-feldspar biotite granite and a gneissoid granite with altered biotite.

Sample No. 3

A two-feldspar red granite (biotite), fairly fresh. A gray granite (biotite) weathered. A gray granite badly weathered. A two-feldspar granite (biotite) badly weathered. Sample highly variable piece by piece.

Sample No. 4

A schistose metamorphic rock, varying considerable in composition, many of the particles coated with calcium carbonate.

Sample No. 5

A schistose metamorphic rock, more uniform than sample No. 4, and finer grained with darker minerals. Considerable biotite mica present which has been altered to chlorite in some specimens.

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TABLE 4

The following samples were not marked for our identification. They were, however, examined and may be identified by the number of the photographs.

Picture No. 716-717

Temperature 1500°F/3 min.

A sandstone, high in iron oxide, firm in body, some fractures.

Picture No. 748-749

Temperature 1800°F/3 min.

Hornblende schist, some fractures recemented with epidote, new fractures, little alteration of minerals, considerable feldspar, secondary mineral epidote, different samples vary in composition. Smaller samples show greater weathering and as a result are more friable.

Picture No. 663-664

Temperature 1250°F/3 min.

Feldspar and quartz, not appreciably effected by heat shock.

Picture No. 671-672

Temperature 1250°F/3 min.

Quite similar to materials shown in picture 748-749 but effected less by lower heat shock.

TABLE 4 (continued)

Picture No. 728-729

Temperature 1500°F/3 min.

A mixture of gneiss and schist, fine of grain, few fractures, fairly firm.

Picture No. 718-719

Temperature 1500°F/3 min.

Gneiss, thoroughly altered and disintegrated.

Picture No. 746-747

Temperature 1800°F/3 min.

This sample appeared to be similar to sample No. 4 of the San Gabriel gravel. Minerals altered, especially the micas, badly weakened.

Picture No. 785-786

Temperature 2000°F/3 min.

Appeared to be similar to sample No. 4 San Gabriel gravel, badly fractured, separated on bedding.

Picture No. 789-790

Temperature 2000°F/3 min.

Schist structure highly fractured, alterations of micaceous minerals pronounced resembles sample No. 5 of San Gabriel gravel.

No attempt was made to make a detailed petrographic examination of the materials since it was evident that there was a wide degree of variability item to item in each sample. Only the gross effects relating the failure to structure, mineralogy, and temperature were tabulated. It was noted that the major failures occurred above 1250°F. The three main types of failure were: (1) through quartz inversion, especially when the quartz grains were large; (2) failure through mica exfoliation, especially pronounced where the mica was in the advanced weathered condition, and (3) failure through exfoliation of Shistose structure (through expansion and breakdown of mica, chlorite, quartz, etc). Though preliminary, one may point to these three items as quite important to any aggregate specification for use above 1500°F.

3. PLANS FOR NEXT QUARTER

Due to the behavior in our tests of the concrete (Section 2.1) designed with diabase aggregate and its frequency of occurrence additional tests are planned on concretes using this aggregate. It is suggested that it be included with other aggregates now being studied at NACERELAB.

It has been found^{6/} that carbonization occurs during curing treatment resulting in a greater weight increase for the smaller specimen. (In proportion to weight-area ratio.) To determine the extent of this weight increase due to carbonization (Section 2.2) it is planned to analyze a series of the concrete specimens for carbon dioxide.

^{6/} E. T. Carlson and C. M. Hunt, N.B.S. Project 0906-11-0923, Chemical Properties of Cementing Materials.

The first part of the report is devoted to a general
description of the country and its resources. It is
then divided into two parts, the first of which
deals with the physical features of the country, and
the second with the human population. The first part
describes the topography, climate, and natural resources
of the country. The second part describes the
population, its distribution, and its economic activities.
The report is written in a clear and concise style,
and is well illustrated with maps and photographs.
It is a valuable source of information for anyone
interested in the country and its resources.

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Further work is planned on the design, fabrication, and testing of concretes containing AlCOA - XCA-25 cement (Section 2.4) since this cement is unusual in the concretes made with it had an exceptionally small percent reduction in strength resulting in heat treatments. This type of cement is now marketed by several manufacturers.

Additional data will be taken to determine the pressures developed in concrete during heating (Section 2.5).

4. LITERATURE

A review of the following articles was made during the month:

1. La capillarité des bétons manufacturés par L. Marill
Revue des Matériaux de Construction et de Travaux Public
Edition C, February 1956, No. 485.

Summary

The proper $\frac{W}{C}$ ratio is the primary condition necessary to obtain a low absorption concrete. When the water does not completely fill the normal voids between the grains of cement the voids persist after hydration and create a path for water penetration and at best forming a less dense concrete.

The fineness modulus of the aggregate should be the one that would develop a compact concrete.

In a very porous concrete the water penetrates thru the large pores for a distance of several centimeters but can travel thru large thicknesses by following the small cracks to the interior of the large pores.

A concrete can carry an excess of material that is similar in fineness to the cement. However, if a small portion of this material is of the size of 5 microns, clay or other materials smaller than 1 micron should not be used. The addition of clay was not included in this work since its inclusion is generally known to be harmful.

The cement content is not the predominating factor. Concretes may be designed that will develop capillaries when the cement content is as low as 160 Kg/m^3 , nevertheless, a low porosity was obtained by going below the 10 percent cement content using the Joisel method of concrete design.

The method of curing has a marked influence on the water penetration of concrete. The curing in water has a favorable action in reducing the area of the capillary network.

The use of an additive to a concrete that already has good density reduces its porosity.

The use of wax, rubber etc and the techniques of impregnation is another method of obtaining impermeable concrete.

In addition to the interest of building construction where water tight walls are desirable, the study of the porosity of concrete can furnish indications as to the speed of drying or wetting and consequently the effect on expansion and contraction observed in construction.

2. Concrete Pavements on the German Autobahnen, F. H. Jackson and Harold Allen, Journal of the American Concrete Institute, Vol. 19, No. 10, June 1948.

This publication is merely an Engineers' report on the durability of concrete pavements where particular care was taken in placing and curing concrete. No data is given on design or mix except accuracy in grading aggregate. Since this publication is readily available a more detailed summary is not considered necessary.

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